AMES

Combination Ice and Electric Plants

Electrical Engineering

B. S.

1911

COMBINATION ICE AND ELECTRIC PLANTS

BY

ALBERT WILSON AMES

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

CONTENTS

INTRODUCTION

Artifical ice or mechanically made ice dates back to an early period, but only in comparatively recent years have methods of manufacture been developed sufficiently to make an industry of manufacturing ice. Now, nearly all towns in the South whose population is past the thousand mark have an ice factory. The southern towns are notable in this respect in as much as natural ice can not be harvested there, but many localities having natural ice also support a well paying artificial ice plant. This shows the low cost of artificial ice which falls below the cost of harvesting natural ice in many instances. Mechanical power is of course required to manufacture ice.

The electric light plant must have enough capacity to carry it's heaviest load which lasts for only a short period each evening. The machinery and consequently the investment, lies idle or runs lightly loaded a large percentage of the time. This is an uneconomical and inefficient condition.

It is the object of this thesis to discuss the advisability of using the idle available power of an electric light plant to manufacture ice in combination with operating the electric plant. Any locality large enough to support an electric light, heat and power plant will afford a reasonable ice market. The ratio of cost of production to selling price or profits,

then, is the principal consideration. The cost of ice manufacture in independent plants is known and in the following it is shown why a combination plant can turn out ice cheaper than an independent ice factory.

There are numerous examples of refrigerating and power plants which are not considered commercially here. These are the equipments of large hotels, steamships, private plants, such as butchers and packers.

The production of ice as well as the production of electricity has reached a high state of developement but a combination of the two under one management is new and not extensive, therefore the sources of information on the subject are very limited.

THE COMBINATION ICE AND LIGHT PLANT

Ice has become a necessity now-a-days but its cost after transportation would make it prohibitive for the ordinary uses. The small electric lighting plant operates at a comparatively low efficiency and very little can be done to encourage a more generous use of current in a small town. If the lighting plant runs only at night there are many idle hours of the investment, while a plant which runs continuously has a very light load or a small percent of its machinery working. For many reasons it has been found profitable and perfectly satisfactory to operate an ice factory in direct connection with an electric lighting plant. These reasons for combining the two industries are the main consideration in this thesis.

ICE-MAKING PROCESSES

Ice is commonly made for commerce by either one of two methods, the ammonia compression or the ammonia absorption process. In the absorption system the ammonia is liquified by first being brought under pressure by heating with steam then the heated gas under the pressure is cooled by water and liquifies. In the compression system the ammonia vapor is liquified in a compressor or brought to the pressure where by it liquifies upon cooling. Then the liquid ammonia in both systems passes thru a nozzle into the expansion coils which are immersed in brine or whatever is to be cooled. On vaporizing and expanding the ammonia absorbs heat from the brine and passes again and again through the cycle, the heat absorbed in each case being taken off by the cooling water after compression.

The compression system is less expensive to install and may be motor driven but must be in individual units, where as the absorption system has to be from its nature near the steam supply but operates more economically on fuel basis. It has a high initial cost but may be made to any capacity and increased by any desirable increments from time to time as occasion demands.

The compression system is used in all smaller installations and is the most desirable for the average combination plant.

ICE-MAKING LOAD

The fundamental idea in making ice in an electric plant was to fill up the valleys between the peaksof the load thus keeping the machines working nearer full capacity and consequently at highest efficiency. Modern ice making processes will freeze water in less than24 hours so that the daily ice harvest may be pulled while the heavy electrical load is on, the freezing going on during light electrical load. The market for ice is greatest just when the demand for current is the least. Operating an ice plant during the day has kept circuits alive which would have been shut down ordinarily. This made a day-time electrical load grow by the installation of fans,flat irons and the many new electrical household devices. In such a case the plant has been changed from a very uneconomically operated night plant to a 24 hr. plant at better efficiency, more output, yet the same rate of income.

In many cases the income and profits from the ice end of the business greatly exceeded the electrical profits. There are several side lines or by-products which a small plant can handle such as coal, steam heating, and chemical refining but ice is the best finanically and is not restricted to climate, location or natural resources as the others may be. There is always a market for ice especially in the South. The only requirement then is to manufacture it at a price which can realize good returns.

COST OF ICE

In addition to the regular lighting plant attendants, a small number of men will be needed to handle the ice plant. This number of men dependsupon the extent of the ice business and the duties of the light plant operators. The addition of the ice-making machinery will not increase the engineer's and fireman's duties beyond the ability of the number of men employed but will warrant paying more to secure better men to handle the machinery. The only competitor the ice manufacture can have is the natural-ice dealer.

Under the most favorable conditions natural ice can be put up at less expense per ton than artificial ice but usually the cost of harvesting, shrinkage in storage, transportation, hauling and cleaning, brings its cost far above that of even a small plant's product to say nothing of the superior grade of the artificial ice. As artificial ice from an independent factory nets greater returns than natural ice, a combination plant could certainly profit by supplying ice since its production would cost them less than the independent ice factory. From estimates it is found that independent artificial ice costs in the neighborhood of $1.60 per ton to manufacture against $1.10 per ton by a combination plant. Natural ice cost runs above either of these figures and seldom below the lower figure $1.10 per ton.

OPERATING COMBINATION PLANTS

There are considerations in the detailed operation of a plant which are governed by the size of the plant. In general combination plants have only the steam boilers in common between the ice and electrical machinery. The smaller plants use the exhaust steam from both the electrical units and ice machines to supply the water for ice. In case the plant is large enough or so proportioned as to have enough exhaust steam from the generator engines for ice and heat it is economical and advisable from the operating stand point to drive the ammonia compressor by electric motor. This is especially so if the electrical system is alternating current and a synchronous motor may be used and improve the power factor at the will of the operator.

The power required to supply an ice machine may be taken at about two kilowatts per ton of ice capacity. Some of the best plants produce ice at the rate of one ton for 50 K. W. hrs. power consumption. At a sale price of $3.00 per ton and deducting all costs and expenses there is a net profit of 1 1/2 cents per K. W. hr. used in making the ice. An average of 600 pounds of ice per day may be made per horse-power of plant capacity but this ratio varies thru a wide range and is governed mostly by the market for ice. Here it might be stated that as well as increasing the electrical demand by circuits alive the establishment of good artificial ice will create a habit of using ice

which will grow to a very profitable one to supply. There may be allowed on an average of one ton ice making capacity for every 150 inhabitants in a community, altho this ratio varies as much as ten fold between maximum and minimum limits. The main governing function of these ratios is the climate or location of the plant.

There are no restrictions, due to combining the two, to advancing either the ice-making or the electrical generation to their highest points of refinement. In fact this can be more easily and economically done with the combination. As a result of inquiry from some 200 combination plants it was found that 97 percent were highly successful to the extent of some mangements being enthusiastic about their results. One thousand dollars per ton capacity may be used as a good figure to estimate the total cost of aiding an ice equipment to an electric plant. This includes the land and building.

LOCATION OF PLANTS

It is found that the new idea of combining ice and electric plants is most readily taken up by the more progressive and newly developed territories. The south western states, with their modern high-class construction, in general, have the predominating number of combination plants.

Combination plants are found to be chiefly located in smaller towns and cities, varying from 50 K. W. to 500 K. W. rating. The relative number of plants as to the population is divided as follows:-

Under 2500 inhabitants	48 plants
2500 to 5000 "	48 "
5000 to 10,000 "	27 "
Cities above 10,000 "	15 "

The smallest station with an ice-making auxiliary is at Ness City, Kansas with a 5 ton machine in a community of 750 people. The number of combination plants in the states are recorded as follows:-

Oklahoma	22	West Virginia	5
Kentucky	18	Nebraska	4
Illinois	16	Iowa	4
Missouri	15	California	4
Kansas	13	Georgia	[illegible]
Arkansas	10	S. Carolina	3
Virginia	8	New Mexico	3
Colorado	4	Wisconsin	2

Indiana	4	Michigan	1
Connecticut	2	Nevada	1
New Jersey	2	New York	1
Florida	17	Ohio	1
Tennessee	8	Oregon	1
Louisiana	7	Pennsylvania	1
Mississippi	5	Washington	1
N. Carolina	5	Hawaii	1

Texas has the largest number of combination plants, being of the greatest area and rapidly growing in population and settlements. There are 83 ice-electric plants in Texas. As might be expected we have the largest number of plants in the Southern states where the ice market is greatest.

AN ICE-MAKING ELECTRIC LIGHT STATION IN FLORIDA

This plant gives an example of the gain in adding an ice machine to a small electric plant. The electric plant alone, after two years operation, was just meeting expenses. The load was lights for streets and stores which turned all right, paying a low rate for services. The plant became over loaded so that waiting customers could not be connected. It was decided to make some additions to make the enterprise operate on a paying basis.

A new generator of two and one half times the capacity of the old one was installed to supply the electric load and its additional power capacity. The absorption system of refrigeration was used. There was a comparatively large market for the ice, which was steady from February to October, the season when fruits and vegetables are shipped to the North and West. This ice-making was the profit end of the business in that its income was three times that of the electric plant alone. The same men were used for the attendance to the electric and ice-making machinery up to working over half the ice making capacity of the plant beyond which additional help was required. Fuel required for running the ice machine was very little additional to that required to keep the light load.

The relative figures for the operation of this plant are given in the following, considering the cost of electric output equal to the expense of producing it and represented by

100, then the total output as represented by 400, the ice output being three times the electric output. The expenses of the total output will be double or 200 due to the additional help and fuel required. The following table shows these relative values.

	Output	Expense	Profit
Electric plant alone	100	100	000
" " and 1/4 ice capacity	175	100	75
" " " 1/2 " "	250	100	150
" " " full " "	400	200	200

The largest item of expense was the pay to the attendants so that operating at loads which required the least attendance in proportion to the output gave the greatest percent profit.

This plant, at first, operated at night only then by running the ice plant day time and keeping some house and store circuits alive also a day time demand for electrical power soon grew. A small consideration made such a minor plant as this one a profitable interest.

COMBINATION PLANT AT STERLING, COLORADO

Here the plant was originally designed for making ice in connection with electric energy. The population of Sterling was 4000 and the plant was made to accommodate a growth to 8000, with a limited expenditure. Boilers of 350 H P were installed with room for half again that capacity. Induced draft was installed at less cost than a stack and the operating expense was considered as offset by the control of the draft available. There were two generators one 75 K. W. and the other 150 K. W. installed with room for another large unit.

The ice-making machinery was of 10 ton output per day. The exhaust steam was reboiled to expel the air, then used for the supply from which the ice was made. This plant has an ice storage room to equalize the fluctuating demand. The maximum demand being over two car loads for any one day.

This plant does not use its refrigerating for any cold storage as there is no demand. So, for a simple combination plant in a small growing town this presents an ideal example.

HILLSBORO PLANT

A complete system of records and books are kept at the Plant at Hillsboro, Illinois, therefore a detailed account of the operation of the plant may be obtained.

This company started as an electric plant which grew into a small central station serving a number of neighboring towns with a total population of 8000. The rated electrical equipment is 290 K. W. and an ice machine of 20 tons per day capacity. The ice machine is steam driven but there is enough exhaust steam to supply the ice tanks from the day electric load so that there would be economy in having the ice machine motor driven. Seventy-two percent of the energy sold by this company is accounted for, the remaining 28% being all losses, including line, transformer and meter losses. The operating force of this plant may be taken as an economical one and for the 290 K. W. 20 ton ice plant is as follows:-

One Superintendent

" Chief Engineer

Two Assistant Engineers

" Firemen

One man (Arc-lamp trimmer, wireman and meterman)

Two ice pullers

One ice salesman

Three teamsters

Two men for a small amount attend to the emergency

work and small repairs at the substations in the surrounding towns.

Originally the company bought city cooling water for its ice plant then in 1909 built a cooling tower capable of cooling 200,000 gallons per day at a cost of $3000.00. The city water cost 3 cents per 1000 gallons and the tower reduced the monthly water cost from $281.00 to $15.00. Fully alive to the importance of keeping accurate and systematic accounts, this management can testify as to the financial advantages of combining electricity and ice making under one organization. They found that the addition of an ice business increased the gross income of the plant about 20 percent with a very slight additional cost thus greatly reducing the cost of fuel and equipment per unit of energy produced.

One year's accounts, from November 1908 to November 1909 show an output of 372,918 K. W. hrs. which brought at 6 cents per K. W. hr. $22, 696.94. The ice income was $12,393.37 and for steam heating $4,121.87. Combining these the real output on a money basis is equivalent to 644,386 K. W. hrs. making the coal cost 0.74 cents per K. W. hr. which compares favorably with the best practice in large stations.

The total depreciation is considered as 6 percent of the total actual investment, and the company's Stock pays

dividends of 6 percent. The returns from the amount invested are abnormally high compared with those of other plants of the same investment due to the ice making addition together with good maintenance. The good maintenance and management is shown by the high receipts from the electrical end alone.

All the minor details of this Hillsboro plant regarding its lines, machines, accounting system and many detailed tables are given in an article in the Electrical World for March 3, 1910 from which this account was taken.

CARUTHERSVILLE, MISSOURI

A combination ice-making and lighting plant at Caruthersville, Missouri is an interesting one. This plant is remarkable for its growth, especially in the ice business.

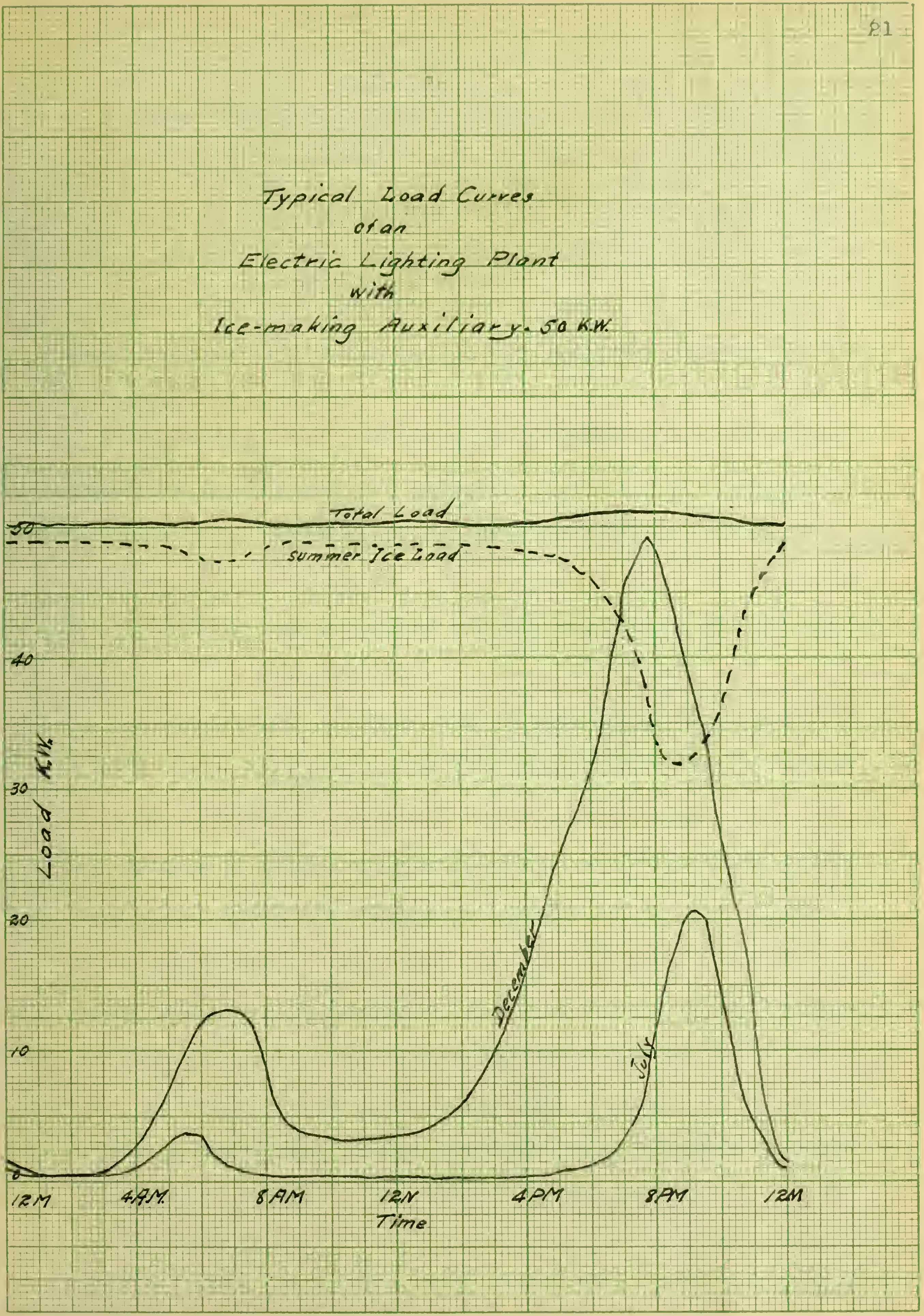
The town had 1,800 inhabitants when the company decided to put a 4 ton ice machine in the power plant. In five years a new building and a 25 ton ice machine were in operation. The population had increased over 100 percent also, but this is against 480 percent increase in plant capacity. Cold storage and ice storage rooms are operated in connection with the plant and together with desiring a substantial building the company built a fire proof building guaranteed not to loose by transmission thru its walls over two B. T. U. per degree difference in temperature every twenty-four hours. Plans were made and carried out whereby the complete charges were made without shutting down the plant. Room was provided for addition as growth demanded. During the day sawdust is burned but at night coal is used since the sawdust is burned as fast as it is delivered, which is not at all at night. The ice making equipment is of the latest type using distilled water from the condensed steam. The cold storage rooms are cooled be brine pipes strung around on the walls.

This company realizes a large profit but does not keep an itemized account altho it is well maintained.

CURVES

The curves shown on the following page are general curves for a 50 K. W. plant. The electric load curves are shown for both the extreme seasons, of a north central location, July and December. The ice machine load curve is shown for July and August which is the time of greatest demand for ice, then the total load curve, being the sum of the ice machine and electric load, shows a constant load at full capacity which is the most efficient operating condition. The winter lighting load is shown, which indicates more electrical energy than the summer load so less power is available for ice. This in many cases may be desirable, because there is not the demand for ice in the winter months. In both cases the plant may be worked to its full capacity by varying the ice load inversely as the lighting load varies.

These curves are general curves but typical of all lighting loads.


Typical Load Curves
of an
Electric Lighting Plant
with
Ice-making Auxiliary - 50 K.W.
Total Load
Summer Ice Load
December
July
Load K.W.
50
40
30
20
10
0
12M
4AM
8AM
12N
4PM
8PM
12M
Time

CONCLUSIONS

There can be no doubt but that there will be profit in combining an ice-machine with an electric lighting plant. There is no limit to the mininum size but for very large cities where all efforts must be concertrated there are many details which are minor in the small plant but prohibit a consideration of ice-making for the extermely large central station.

The reasons for increased ice profits by a combination plant may be outlined as follows:-

1. Saving in boiler operation by working them at a higher efficiency.

2. Attendants are kept busy and the employment of more competent men is warranted.

3 Ice load comes just the time of year when the electric load is least and the ice machine can be shut down entirely if necessary during the short evening peak load.

4. Saving in water, as cooling water can be used for boiler feed water and distilled water frozen.

5. When supplying heat from the plant in winter more exhaust steam will be available and also more distilled water for ice without resorting to live steam for heating.

An installation of an ice-making machine will not only increase the income of the plant but will undoubtedly increase the demand for electrical energy. There is only one reason

why a combination ice-light plant will not pay even under the most adverse conditions and that is poor management. As has been found in many instances the ice end of the business will net greater returns when operated only during three summer months than the electrical profits during the entire year.

Any electric light and power plant except the very largest can increase its profits by installing an ice-making auxilliary more than in any other way. In the case of the large city central station the employees' duties keep them fully occupied in both office and plant. A city station is usually crowded for space and requires all the facilities available for coal, water, supplies etcetera in the production of electricity alone. The distribution of ice to various parts of a large city adds prohibitive expense to a central ice plant. Besides these reasons just stated, combining an ice plant with a large electric plant, would greatly complicate an already very involved system of management and accounts, which alone would not warrant a combination arrangement. However, in the case of large cities, small motor driven ice plants in various parts of the city, could operate to advantage by buying power from the central station at a flat rate. This arrangement is not a combination plant.

In all cases it is evident that ice may be manufactured in conjunction with an electric power plant at a minimum cost of production.